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A. C. True, Director.

SUPPLEMENTAL REPORT ON DRAINAGE IN THE FRESNO DISTRICT, CALIFORNIA.

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A preliminary report upon the drainage of the Fresno district of California was issued from this Office as Circular No. 50, in May, 1903, in which plans and estimates for the drainage of about 25 square miles of fruit land were submitted. The quantity of water which the proposed drains were designed to carry was determined from data of an unsatisfactory character. For the purpose of securing more reliable knowledge of the quantity of water that should be removed from the soil in order to prevent the water table or plane of free water from rising nearer than 5 feet from the surface, small wells were sunk about 8 feet deep on Fruit avenue, beginning at Church avenue and continuing south at intervals of one-half mile for a total distance of 3 miles. This line of wells, seven in number, crossed four distributing canals, so that the water line as determined by consecutive measurements made from the top of the several well boxes would represent similar conditions in other parts of the district. Levels were taken to determine the elevations of the surface and of the tops of the well boxes, so that a proper representative profile could be made. Measurements of the height of free water in the wells were made weekly, except during the first month, beginning with February 28 and ending with June 30. These, when platted for the monthly variation (fig. 1), show the total rise for each month, and, when tabulated, show the weekly fluctuations of the ground water, both of which particulars are useful in determining the quantity of water that should be removed each day in order to maintain its proper level in the soil. These measurements show several significant facts, among which may be enumerated:

(1) On February 28, the time at which the first measurement was taken, the water was 4 feet from the surface at the north end and 6 feet from the surface at the south end, a line connecting the water heights in the several wells being reasonably uniform.

(2) The canals crossed by the line of wells did not appear to affect the general uniformity of the ground water line.

(3) The average rise of water from February 28 to March 30 was 0.5 inch per day, the maximum average daily rise in any one well being 0.6 inch.

(4) The greatest average daily rise for any week between March 30 and April 25 in any one well was 0.5 inch, and between April 25 and May 23 the greatest average daily rise for one week was 0.38 inch.

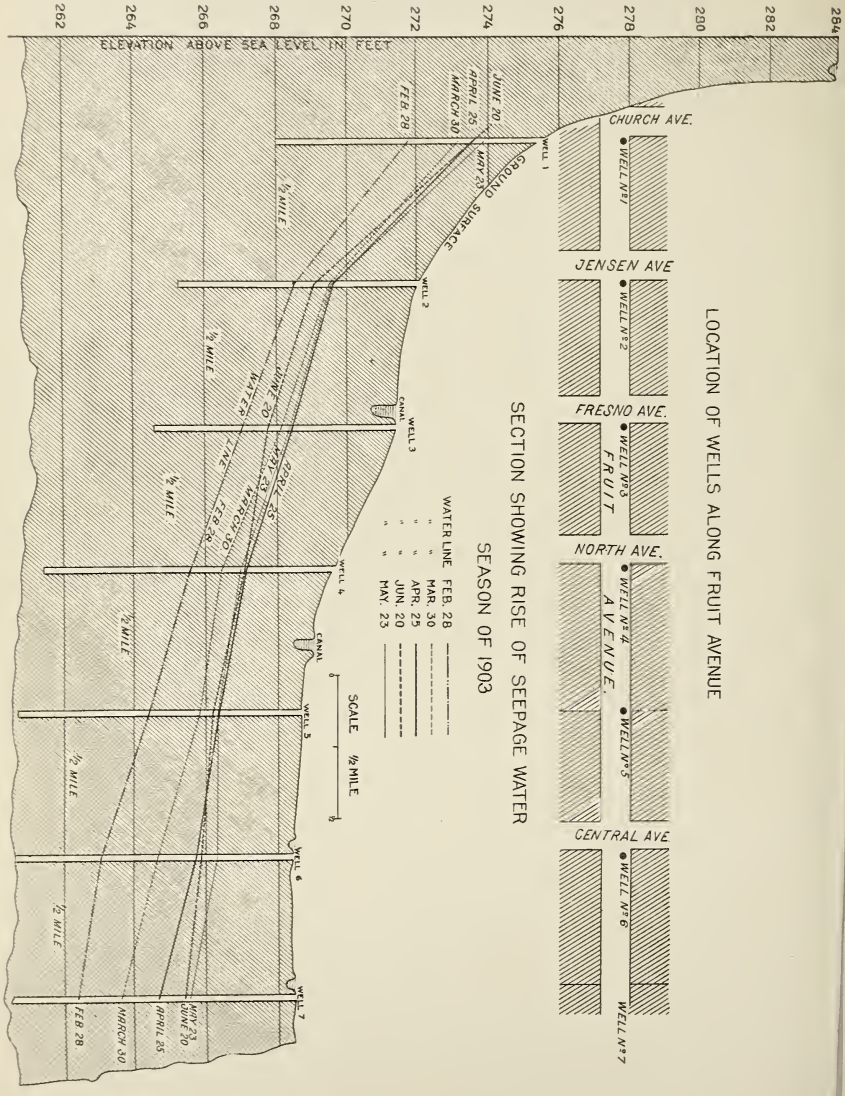

FIG. 1.—Diagram showing the location of test wells and the rise of ground water therein in the Fresno district, during the irrigation season of 1903.

(5) From May 23 to June 27 the water line fluctuated within narrow limits, remaining from 24 to 36 inches from the surface.

(6) The greatest rise of water during the season after February 28 was 40 inches, and the water line rose to within 24 inches of the surface.

The question of how much water must be removed from the soil daily in order to maintain the free water of the soil at the depth at which it was when the first measurement was made, will depend upon the interspace between the soil particles and the quantity of capillary water which should be retained to furnish the proper moisture. The interspace of volcanic ash soils, as determined during the past year by the California Experiment Station, is 55 per cent of their volume, hygroscopic water being found to occupy 11 per cent of the total volume. The precise volume of space required for capillary water has not been accurately determined for these soils, but may safely be taken at 25 per cent. This would leave the space occupied by free water at 30 per cent of the entire volume of the soil, so that 1 inch of rise in the water line represents 0.3 inch of water more than is required to furnish the desired amount of moisture.

The drainage required for the soil along the line of the seven wells before described, as deduced from the measurements made, may be stated as follows:

The daily rise of ground water between February 28 and March 30, 30 days, was 0.5 inch, the daily drainage required, 0.15 inch.

March 30 to April 25, 26 days, average daily rise of 0.28 inch, daily drainage required, 0.08 inch.

April 25 to May 23, 28 days, average daily rise of 0.08 inch, daily drainage required, 0.02 inch.

From May 25 to June 20 the total variations in the wells showed a fall of the water line except in one instance.

In the plans for drainage submitted in Circular No. 50, issued in May, 1903, by the Office of Experiment Stations and the California Experiment Station, the main drains were proportioned to carry 2.5 cubic feet of water per second, or 0.093 inch in depth of water in 24 hours for each 640 acres. Considering the averages of rise of water line as shown by the measurements, the drainage provided will fall short 0.06 inch per day of removing the full amount of water for the first month. For the second month the drainage would gain 0.01 inch per day, and for the third month the drainage would gain 0.07 inch per day. At the end of the third month, drainage having continued, the water table would occupy the original position, provided there was sufficient free passage of water in the soil, either by natural or artificial means, to permit it to reach the main drainage. After the month of May the quantity of drainage will be slight, though it is reasonable to infer that it will be considerably greater than is indicated by the measurements, since if the soil water is maintained at a low level, a greater quantity of water will be used in irrigation and the supply for the drains will be more constant.

These measurements show that the water of the soil brought to it by either seepage or direct irrigation distributes itself quite evenly, but

accumulates more rapidly in lower levels under conditions now prevailing. If, however, drains should be disposed uniformly through the land, this would not be the case, but each drain would receive an approximately equal share of drainage. However, drains at the foot of a slope, such as we have in the position of well No. 1 in the profile, would be called upon to carry a greater amount of water than others more distant from the slope. It is probable that soil water is deflected by layers of hard pan, which will cause its concentration in some localities, so that the drains will not be taxed uniformly. Drainage will be more urgently needed during the months of March, April, and May than during any other part of the year. It does not seem probable that much drainage will be required after the middle of June.

The bearing which these deductions have upon the utility of the drainage plan proposed is important. The capacity of the drain tile designated for mains on the half-mile lines will be slightly overtaxed during the first month and a half of the season, but the approximate rise of 6 inches in the water line will not be sufficient to bring it nearer to the surface than 5 feet, while during the remainder of the season the capacity of the drains will be ample.

The manner of disposing of the water collected by the main drains that would first suggest itself would be to continue the lines of tile due west, diminishing their grade after they pass the west line of the proposed district until the drains could be discharged on the surface of the plain. This would require a length of 11 miles for some of the drains. The drains elaborated in the plan do not as a rule exceed $2\frac{1}{2}$ miles in length, and the largest pipes are 20 and 22 inches in diameter, the smallest being 8 inches in diameter. Since these will be somewhat overtaxed during the early part of the season through removing a sufficient quantity as nearly as can be estimated to accomplish satisfactory drainage, any plan of extending the drains to a length three or more times that indicated would, if carried out, be attended with disappointing results, unless the sizes should be proportionately increased. It will not be practicable to use pipes larger than 20 inches in diameter in this locality on account of their cost. The effect of extending pipe drains beyond the limits of their capacity is to drain the land at the head of the system at the expense of the lower—to concentrate water at points where the drains are of insufficient capacity, which for lack of outlets will be forced into the soil and saturate it, thus defeating the object for which the drains were constructed. The drains should not flow under pressure for the reason that the soil and drains should at all times be in a condition to receive surplus water.

Such facts as could be gathered relating to this phase of the problem received careful consideration at the time the plans for the drainage of the Fresno district were formed. The further investigations herein described, made to determine with greater accuracy the quantity of

drainage water that should be removed, clearly show that if tiles are to be used for the main drains, the lines can not be safely made longer than shown on the plans. The drains must either discharge into sumps and the water be pumped into the canals or shallow surface ditches, or into deep open ditches constructed for the purpose.

The readiness with which soil water distributes itself and maintains its level in the Fresno soil, as shown by the investigations herein described, indicate that if the land is kept in a drained condition at the depth proposed, much of the alkali now concentrated near the surface may be redistributed throughout the soil above the drains as well as removed by drainage water. The two processes, both of which depend on adequate underdrainage, will bring about complete reclamation under the methods of cultivation now practiced by the fruit grower.

Recommended for publication.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON,

Secretary of Agriculture.

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